INDOOR AIR QUALITY ASSESSMENT

Woods Memorial Library
19 Pleasant Street
Barre, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program

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Background/Introduction

At the request of Ann Meilus, President of the Barre Library Association, an indoor air quality assessment was done at Woods Memorial Library (WML), 19 Pleasant Street, Barre, MA. The assessment was conducted by the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH) and was prompted by catastrophic flooding to the basement of the library in October of 2005. Library staff and volunteers remediated the flood water. Remaining concerns about water damage to building materials and mold concerns prompted the assessment.

On November 10, 2005, a visit was made to this building by Michael Feeney, Director of CEH Emergency Response/Indoor Air Quality (ER/IAQ), to conduct an indoor air quality assessment. The WML is a two-story brick building constructed in 1886 (Picture 1). The library was renovated in 2001, during which a wing to the rear of the building was added and the basement was finished (Blueprint 1, Pictures 2 and 3). The second floor contains storerooms and a museum. The first floor contains the main book collection and offices. The basement, which was extended under the new wing, contains the children's library, activity room, book storage and various mechanical rooms. Both the original building and new wing contain sump pumps. Windows are openable throughout the WML.

The water damage to the library resulted from a rainstorm that delivered an estimated 2.6 inches of rain on the weekend of October 15, 2005 (Weather Underground, 2005). The rainstorm resulted in flooding reports throughout Massachusetts. The flooding and clean up efforts were documented by L. Allen of the WML (Pictures 4 through 8).

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth. Moisture content of water damaged materials was measured using a Delmhorst, BD-2000 Model, Moisture Detector.

Results

The WML has an employee population of approximately 6 and an estimated 100 individuals visit on a daily basis. The tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that the carbon dioxide levels were below 800 parts per million (ppm) in all areas sampled during the assessment, indicating adequate air exchange. It is important to note however, that a number of areas were sparsely populated and/or windows and exterior doors were open during the assessment, which can greatly reduce carbon dioxide levels.

Ventilation is provided by a heating, ventilation and air conditioning (HVAC) system. Fresh air is introduced by an air-handling unit (AHU) located in the basement and distributed by ceiling-mounted fresh air diffusers connected to ductwork, which is then returned to the AHU via ducted exhaust vents. The basement AHU appears to draw fresh air from an intake located at ground level.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. Building staff reported that the system was balanced after the renovation in 2001. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A of this assessment.

Temperature readings ranged from 63^{o} F to 67^{o} F, which were below the MDPH recommended range for comfort. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 38 to 41 percent, which were within or close to the MDPH recommended comfort range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The configuration of the basement level entrance appears to make the basement prone to flooding after extended heavy rainfall. At the rear of the building is a dirt parking lot that borders semi-wetland, which was flooded with water during the heavy October rains (Picture 5). According to renovation blueprints, a catch basin that predates the renovation project appears to exist in the dirt parking lot (Blueprint 2). CEH staff examined the parking lot and surrounding properties for this catch basin, and could not locate it.

At the time of the assessment the basement appeared to be dry, with relative humidity measurements consistent with measurements in upper floors (which did not come in contact with flood waters). Of significance is the presence of a sump pump in the floor of the original library (Blueprint 3, Picture 9), which indicates that the basement had flooding problems in the past, prior to the renovation.

In order for building materials to support mold growth, a source of water exposure is necessary. Identification of the location of materials with increased moisture levels can indicate an existing or potential location of mold colonization. Building materials with increased moisture content over normal concentrations may also indicate the possible presence of mold growth.

In an effort to ascertain moisture content of gypsum wallboard (GW), carpeting and wood a Delmhorst probe was inserted into the surface of GW (Picture 10), carpet and wood. The Delmhorst probe is set to sound a signal when a moisture reading of $\geq$ 0.5 percent in GW or $\geq$ 15 in wood is detected.

Please note, moisture content is detected as a real time measurement of the conditions present in the building at the time of the assessment. The building was evaluated on a cloudy day, with an outdoor temperature of 25 ^{o} F and relative humidity of 49 percent. Moisture content of materials may increase or decrease depending on building and weather conditions. For example, during the normal operation of a heating, ventilating and air-conditioning (HVAC) system, moisture is introduced into a building during weather with high relative humidity. As indoor relative humidity levels increase, porous building materials, such as GW, plywood or carpeting, can absorb moisture. The moisture content of materials can fluctuate with increases or decreases in indoor relative humidity.

Accumulated moisture was measured in basement GW (Picture 11), carpeting (Picture 12) and wood (Picture 13) that were in contact with flood water. As a comparison, all floor, carpet and wood sampled on the first floor had low (or normal) levels of moisture. These measurements indicate that moisture likely continues to be present in porous basement materials weeks after moistening.

The following list are a number of conditions related to the construction of the building or configuration of building components that may be sources of moisture in the basement level floors and walls.

- The basement floor of the new wing is constructed with a 6 mm polyethylene vapor barrier (Blueprint 4). The purpose of a vapor barrier is to prevent moisture penetration through the slab of the basement floor. It is possible that the vapor barrier is allowing moisture to pool between it and the carpet to serve as a source that continuously moistens the carpet and other materials in contact with the floor.
- The exterior wall of the new wing appears to contain fiberglass insulation (Blueprint 4), which was not removed as part of the remediation efforts. Water damaged fiberglass insulation can not only serve as a moisture source, it

also loses its ability to properly insulation the wall cavity, which can lead to cold penetration and ultimately, condensation within the wall cavity.

- The wall coving was not removed during the remediation process (Pictures 7 and 8). Wall coving should be removed to aid the drying process during remediation. If it is not removed, GW behind the coving frequently remains wet, which can lead to mold growth.

Flooding from ground water should be considered to be sewage contaminated for the purpose of clean up (IICRC, 1999). In general, it is recommended that absorbent materials (GW, wall insulation, carpeting, fabrics, books, cardboard, etc.) be discarded once in contact with sewage (IICRC, 1999). Flooring and sub flooring (such as wood and tile) should be evaluated, cleaned, disinfected, dried and sealed when appropriate (IICRC, 1999). These measures should be implemented.

The US Environmental Protection Agency (EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Once mold growth has occurred, disinfection of these materials may be possible. Since GW, plywood and carpeting are porous surfaces; disinfection is likely to be ineffective. Removal of these materials is likely needed to prevent exposure to mold and other associated pollutants.

Exterior wall systems should be designed to prevent moisture penetration into the building interior. An exterior wall system should consist of an exterior curtain wall

(Figure 2, Blueprint 3). Behind the curtain wall is an air space that allows for water to drain downward and for the exterior cladding system to dry. At the base of the curtain wall should be weep holes that allow for water drainage. Opposite the exterior wall and across the air space is a continuous, water-resistant material adhered to the back up wall that forms the drainage plane.

The purpose of the drainage plane is to prevent moisture that crosses the air space from penetrating into interior building systems. The plane also directs moisture downwards toward the weep holes. The drainage plane can consist of a number of water-resistant materials, such as tar paper or, in newer buildings, plastic wraps. The drainage plane should be continuous. Where breaks exist in the drainage plane (e.g., window systems, door systems and univent fresh air intakes), additional materials (e.g., copper flashing) are installed as transitional surfaces to direct water to weep holes. If the drainage plane is discontinuous, missing flashing or lacking air space, rainwater may accumulate inside the wall cavity and lead to moisture penetration into the building.

In order to allow for water to drain from the exterior brick wall system, a series of weep holes is customarily installed at or near the foundation slab/exterior wall system junction (Figure 2). Weep holes allow for accumulated water to drain from a wall system (Dalzell, 1955). Failure to install weep holes in brickwork or burial of weep holes below grade will allow water to accumulate in the base of walls, resulting in seepage and possible moistening of building components (Figure 3).

The exterior of the new wing of the WML consists of a traditional red brick exterior wall and vinyl siding. An examination of the exterior brick walls of this section of the building was conducted to identify the location and condition of weep holes. Weep holes were found above grade. Some weep holes in these walls were open (Picture 14). Of note is that some weep holes were blocked with a wick material (Picture 15). Wicks were originally installed to enhance water movement from the drainage plane. Over time, sediment accumulation turns the wick into a stopper, which prevents water drainage from the exterior wall system. It is not recommended to "use ropes or tubes for weep [hole]s" (Nelson, P.E., 1999).

Conclusions/Recommendations

While the remediation efforts to remove water from the basement appeared to have prevented widespread damage, porous materials that came in contact with the flood water (e.g., GW, carpeting and wall insulation) should be removed. In order to completely remediate the damage created by the flood, a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address overall indoor air quality concerns.

In view of the findings at the time of the assessment, the following recommendations are made:

Short Term Recommendations

1. Remove water damaged materials (e.g. carpeting, gypsum wallboard and wall insulation) in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US

Environmental Protection Agency (US EPA, 2001). Consider replacing carpeting with a non-slip, nonporous material (e.g., rubber matting, tile).

2. Once carpet is removed, use ventilation and dehumidifiers to draw moisture from the cement floor that exists above the slab vapor barrier.

3. During removal of building materials use local exhaust ventilation and isolation techniques to control remediation pollutants. Precautions should be taken to avoid the re-entrainment of these materials into the building's HVAC system. The design of each system must be assessed to determine how it may be impacted by renovation activities. Specific HVAC protection requirements pertain to the return, central filtration and supply components of the ventilation system. This may entail shutting down systems (when possible) during periods of heavy construction and demolition, ensuring systems are isolated from contaminated environments, sealing ventilation openings with plastic and utilizing filters with a higher dust spot efficiency where needed (SMACNA, 1995).

4. Seal any utility holes, spaces in roof decking and temporary walls to eliminate pollutant paths of migration.

5. Seal elevator doors and hallway doors with polyethylene plastic and duct tape. Consider creating an air lock of a second door inside the remediation spaces to reduce migration.

6. If possible, relocate susceptible persons and those with pre-existing medical conditions (e.g., hypersensitivity, asthma) away from the general areas of remediation until completion.

7. Establish communications between all parties involved with remediation efforts (including building occupants) to prevent potential IAQ problems. Develop a forum for occupants to express concerns about remediation efforts as well as a program to resolve IAQ issues.

8. Develop a notification system for building occupants to report remediation related odors and/or dusts problems to the building administrator. Have these concerns relayed to the contractor in a manner that allows for a timely remediation of the problem.

9. When possible, schedule projects which produce large amounts of dusts, odors and emissions during unoccupied periods or periods of low occupancy.

10. Disseminate scheduling itinerary to all affected parties. This can be done in the form of meetings, newsletters or weekly bulletins.

11. Obtain Material Safety Data Sheets (MSDS) for all remediation/decontamination materials used during renovations and keep them in an area that is accessible to all individuals during periods of building operations as required by the Massachusetts Right-To-Know Act (MGL, 1983).

12. Consult MSDS' for any material applied to the effected area during renovation(s) including any sealant, carpet adhesive, tile mastic, flooring and/or roofing materials. Provide proper ventilation and allow sufficient curing time as per the manufacturer's instructions concerning these materials.

13. Implement prudent housekeeping and work site practices to minimize exposure to spores. This may include constructing barriers, sealing off areas, and temporarily relocating furniture and supplies. To control for dusts, a high efficiency particulate

air filter (HEPA) equipped vacuum cleaner is recommended. Non porous materials (e.g., linoleum, cement) should be disinfected with an appropriate antimicrobial agent is recommended. Non-porous surfaces should also be cleaned with soap and water after disinfection.

14. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

15. Remove wicks from all weep holes.

Long Term Recommendations

1. Identify if a catch basin exists to drain the parking lot. If no catch basin exists, measures should be considered to improve drainage from the parking lot.
2. Consider constructing a concrete dike around the basement entrance of sufficient height to prevent water penetration.
3. Given that the library has sump pumps in its basement floor, it is strongly recommended not to install wall-to-wall carpeting in the basement. A non-porous, easily cleanable surface should be used.

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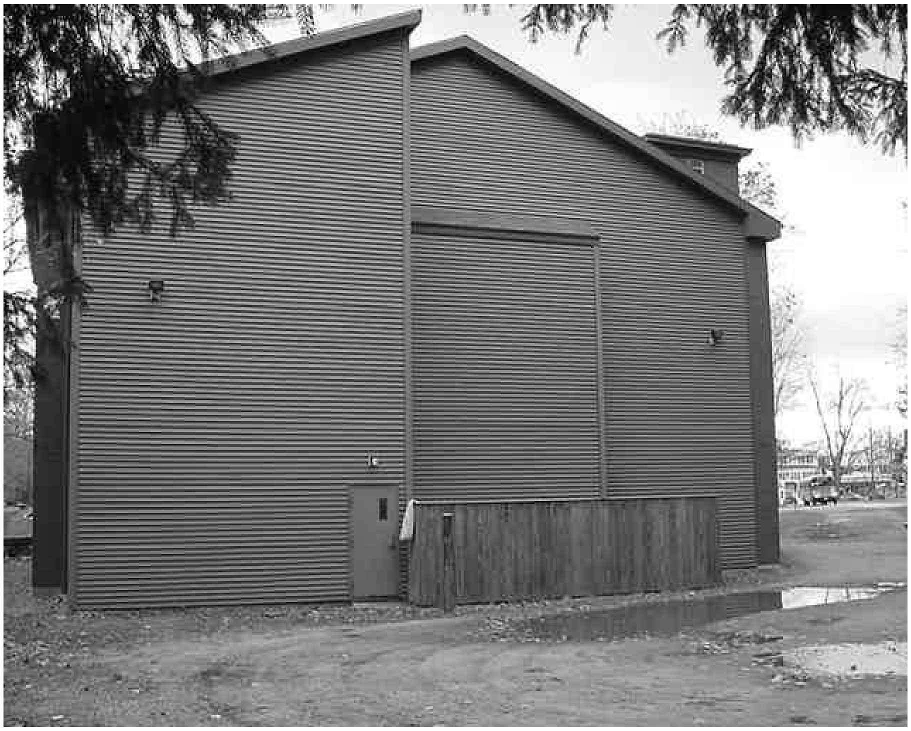
Picture 1

Woods Memorial Library (Original Building Left Foreground), New Wing (Background)

Picture 2

Woods Memorial Library, New Wing, Basement Entrance

Picture 3



Woods Memorial Library, New Wing, Rear of Building

Picture 4

Flood at Woods Memorial Library, Barre, Massachusetts
October 15, 2005

(Taken By L. Allen of the WML)

Picture 5

A flash flood produced water over knee-deep at the Woods Memorial Library on Oct. 15, 2005.

(Taken By L. Allen of the WML)

Picture 6

Two days later: on October 17, the water line is evident on the exterior of the building

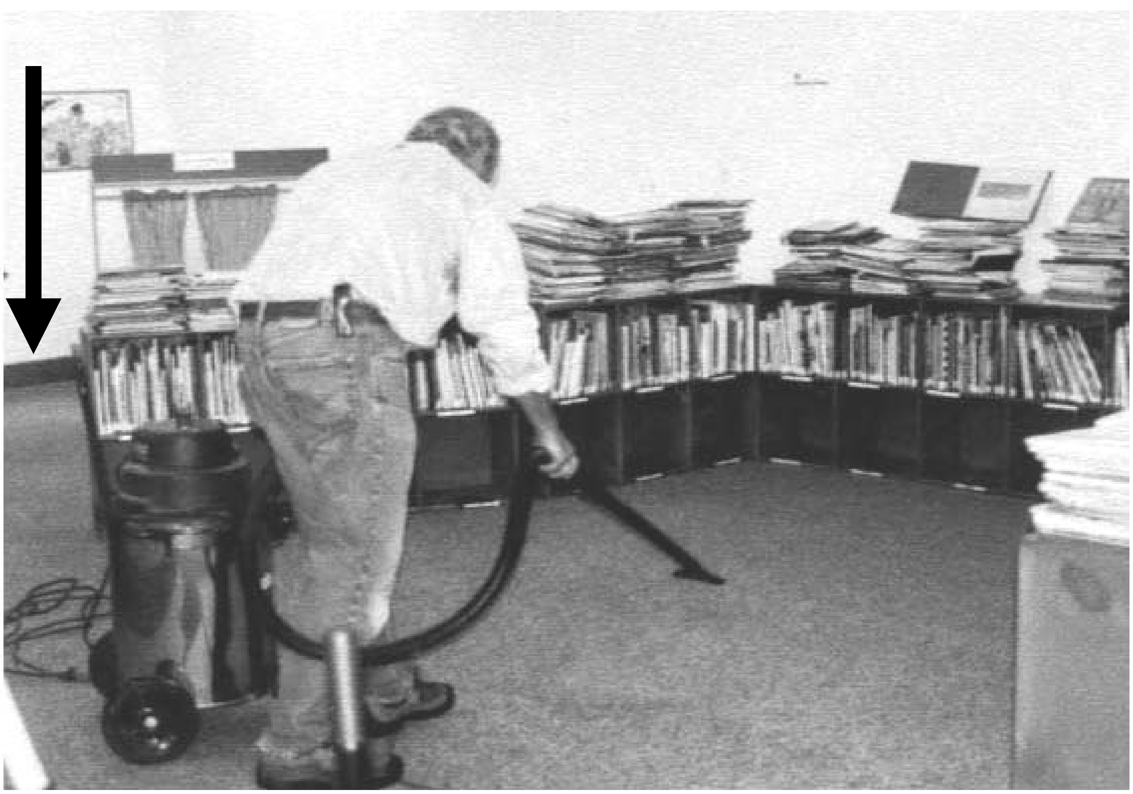
(Taken By L. Allen of the WML)

Picture 7

(Taken By L. Allen of the WML)

Flood Cleanup, Note Coving on Wall (Arrow)

Picture 8



(Taken By L. Allen of the WML)

Flood Cleanup, Note Coving on Wall (Arrow)

Picture 9

Sump Pump, Original Building Floor, Note Carpeting Installed up To Edge of Pump Casing

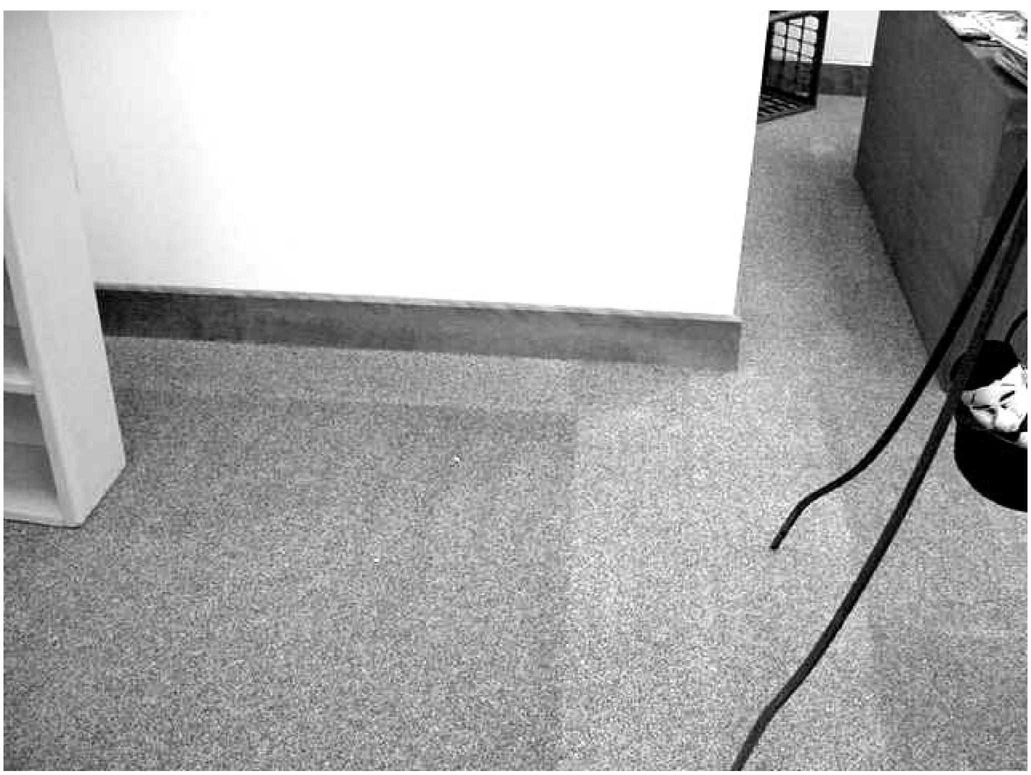
Picture 10

Delmhorst Probe Was Inserted Into Building Wood

Picture 11

Probe Marks in GW in Basement Exterior Wall

Picture 12



Carpeting Stained With Water Sediment

Picture 13

Shelves with Moisture Reading at Its Base, Top of Shelves Had Low (Normal) Moisture Measurements

Picture 14

Open Weep Holes

Picture 15

Wick-ed Weep Hole

TABLE 1
Indoor Air Test Results
WOODS Memorial Library, Barre, Massachusetts
November 10, 2005

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	320	<32	49					Overcast
Museum	507	63	41	0	Y	Y	Y	Passive exhaust vents
Reference room	526	64	41	1	Y	Y	N	Door open
Periodicals	523	65	42	0	Y	Y	Y	
Main stack	503	66	42	1	Y	Y	Y	
Computer area	512	67	41	0	Y	Y	Y	
Main library hallway	523	67	40	0	N	Y	Y	
Children's Room-Basement	444	65	39	1	N	Y	Y	See Microbial/Moisture Concerns section of main report
Activity room-basement	509	66	38	0	Y	N	N	See Microbial/Moisture Concerns section of main report

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1
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November 10, 2005

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Book storage-basement	482	66	39	0	N	Y	Y	See Microbial/Moisture Concerns section of main report Dehumidifier Sump pump

*** ppm = parts per million parts of air**

Comfort Guidelines

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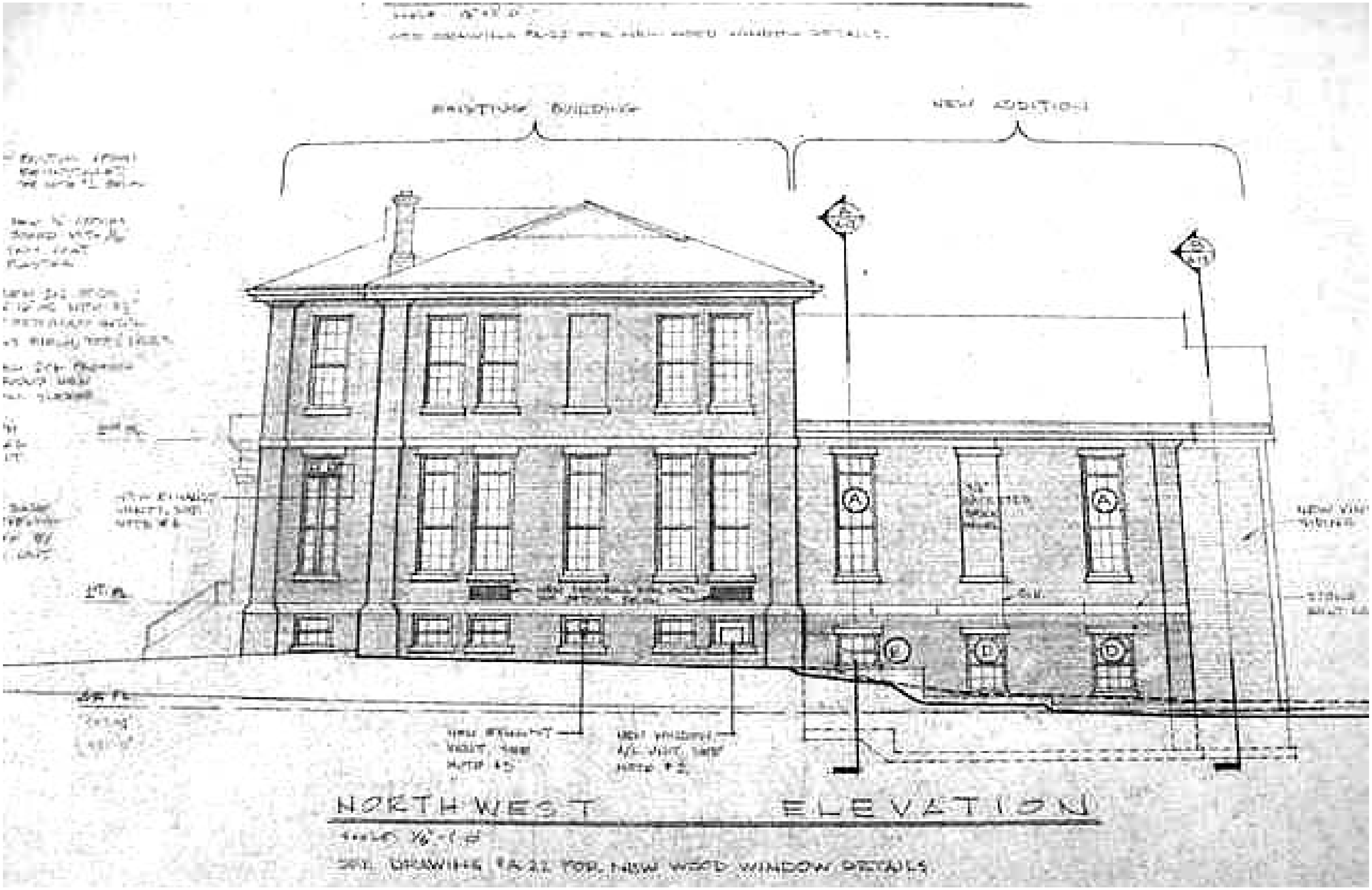
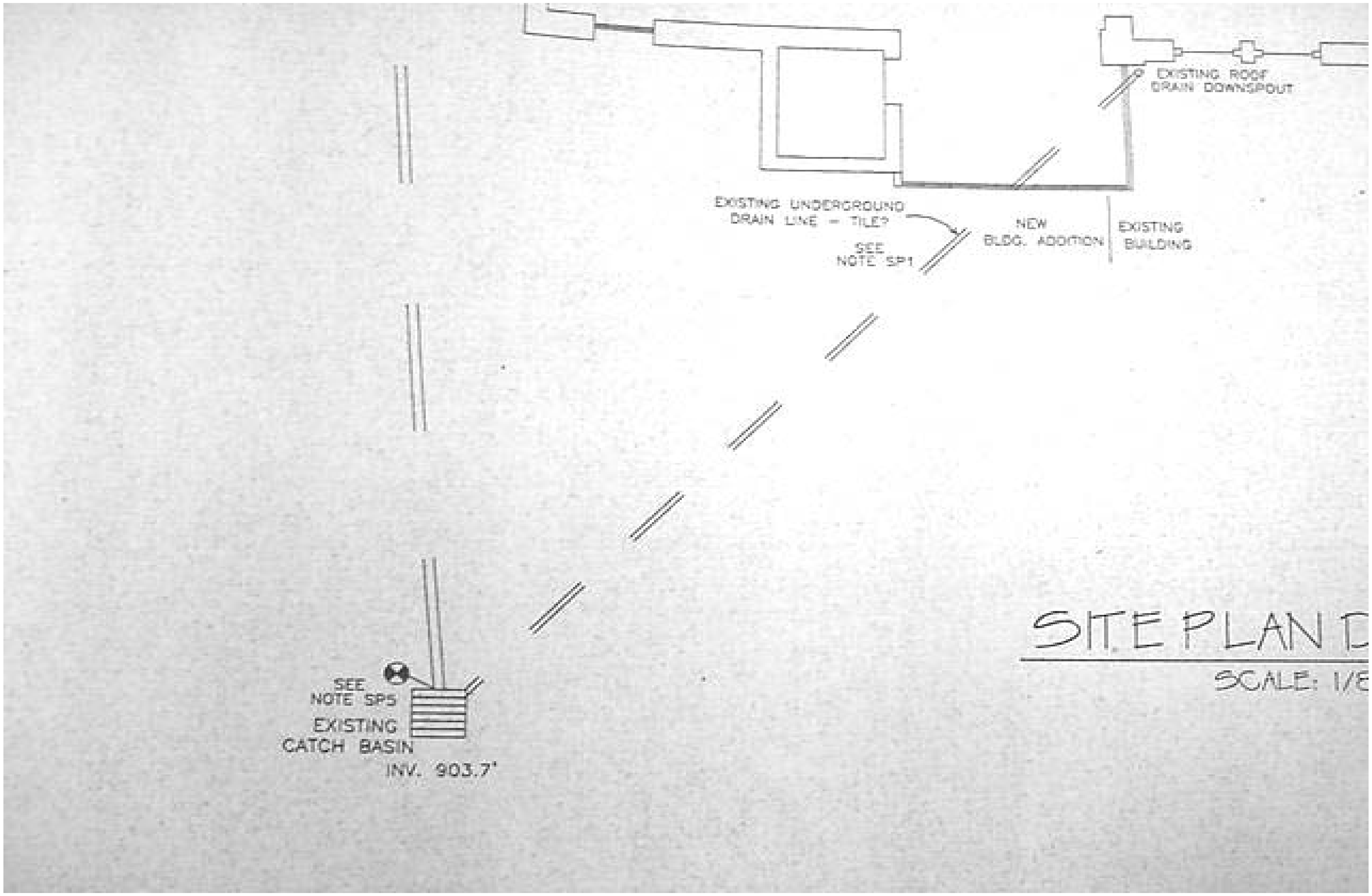
Blueprint 1



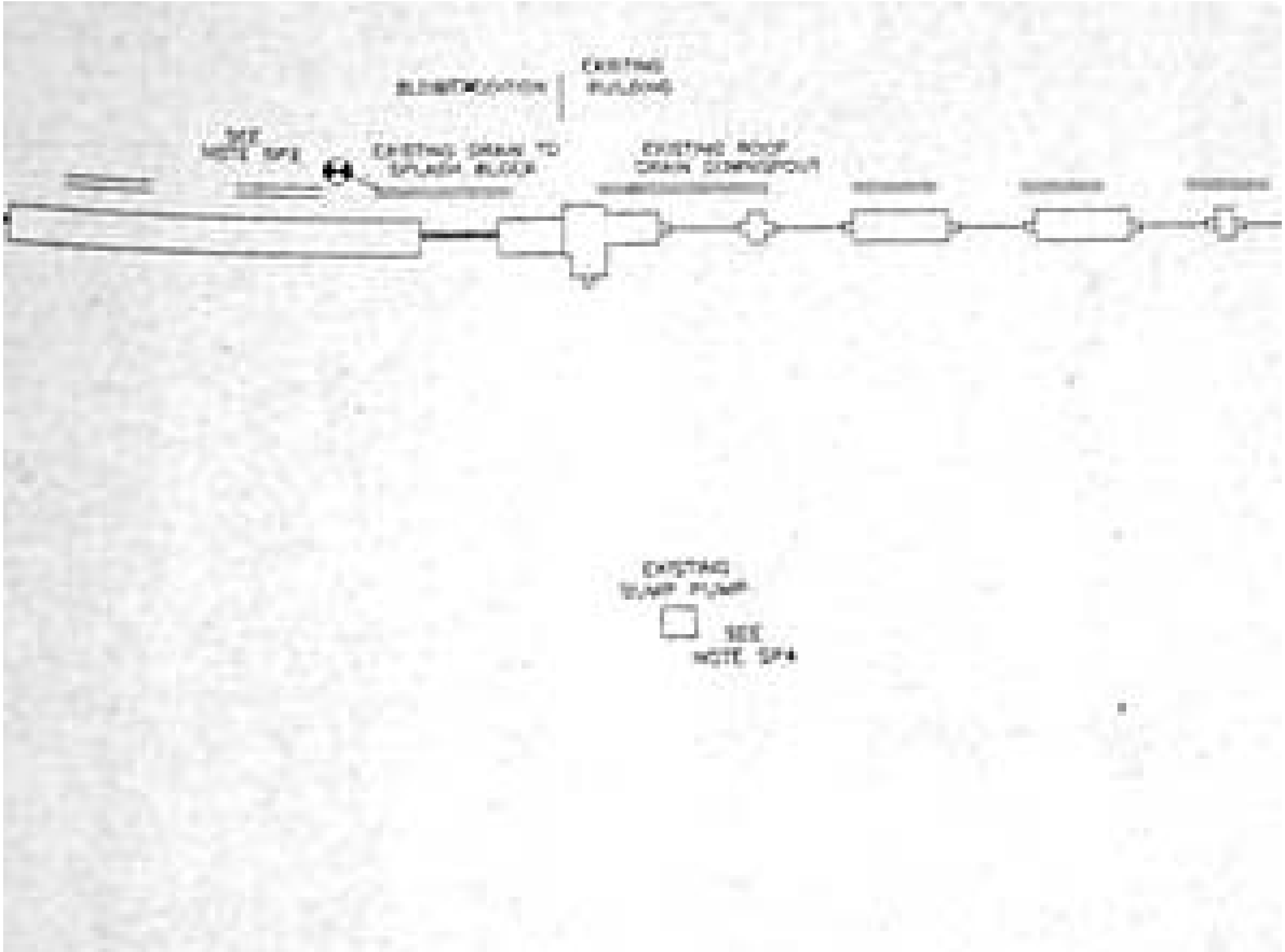
Blueprint of WML Exterior, Detailing Existing Building and New Wing

Blueprint 2



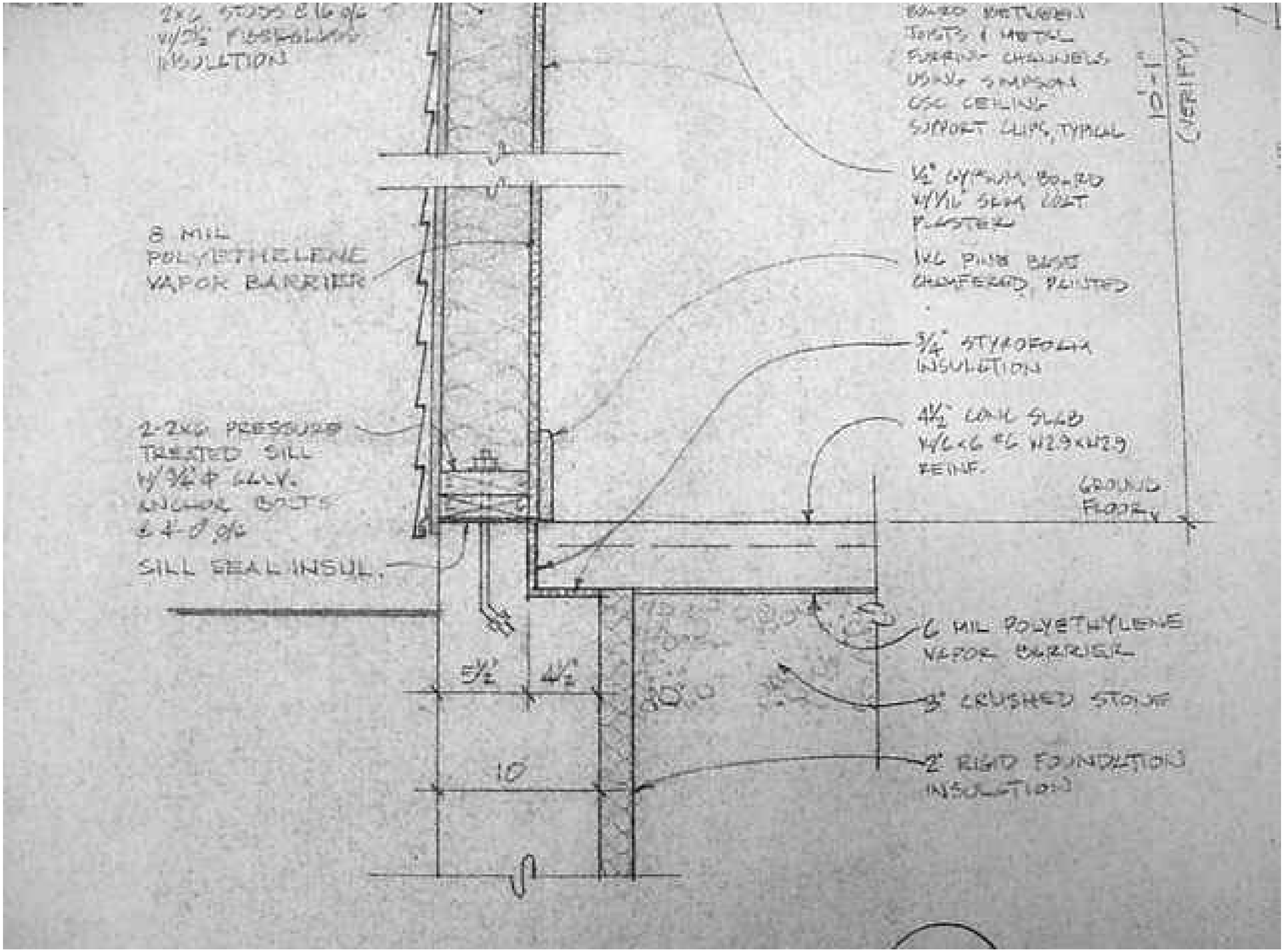
Blue Print Indicating That a Catch Basin Exists Near the WML Property Lot

Blueprint 3



Renovation Blueprint, Denoting Sump Pump Installed In the Existing Floor of WML

Blueprint 4



Blueprint Detailing Vapor Barrier, Wall Insulation and Weep Holes